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# BRUCE NGS 'B' UNIT 8
# TURBO-GENERATOR STABILITY INSTRUMENTATION PROGRAM

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This report presents the final set of results of an on-going program for monitoring turbo-generator stability at Bruce NGS 'B' Units 5 to 8. Information obtained from this study indicates the magnitude and direction of movements of the structural components supporting the turbo-generator during construction and commissioning. The change of turbine table profile, spring support spans, and support column elevations are discussed. This record of initial operating conditions may be of great value in the future during maintenance procedures or run-up programs.

## INTRODUCTION

This report presents the results of an on-going program to monitor the turbo-generator stability of the Bruce NGS 'B' Unit No 8. The measured change of vertical profile of the turbine table operating at 850 MW loading conditions relative to the static operating profile is discussed. Also, horizontal deflections of the turbine table, vertical changes across the Stadelman spring support system, and vertical changes in the turbine table support columns were monitored. Civil Research Department Report No 84-153-K/1/ details the description and location of all the instruments and hardware installed to facilitate the measurements mentioned above. Datum readings for all the measurement stations are also included in the above report.

The data included in this report is interpreted in three ways, where possible. They are as follows:

1. reference measurements to static operating condition,
2. static operating to dynamic operating load, and
3. reference measurements to dynamic operating load - where reference readings were taken at near 100% of the static operating load.



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The reference readings were measured in January, 1984 with the turbine table near 100% loading. The full static operating profile was obtained on January 20, 1987. Measurements were taken May 26, 1987 when the unit was operating at 850 MW, for the dynamic operating profile. Reading changes from January 1984 to January 1987 represent the effects of adjustment to the Stadelman spring supports and vacuum tests. Changes observed from January to May 1987 result from vacuum, temperature increases and the dynamic rotation of the unit operating at 850 MW.

## TURBINE TABLE DIFFERENTIAL MOVEMENT

The vertical profile changes measured on the combination (elevation and alignment) survey stations at the 639 level were interpreted relative to turbine table Station 13, on the southwest corner of the unit. Readings relative to Station 13 detail the contour of the table and indicate any tendencies toward tilting, twisting, or areas of excessive profile change. Figure 1 gives the location of the turbine table and sole plate stations. The data is presented in Table I and the total measured change from static operating profiles to the 850 MW dynamic operating condition is graphically presented in Figure 2. Generally, the ends of the unit have moved slightly upward or remained stationary. The centre of the unit has deflected down with load to a maximum of 0.210 cm (0.083 inches).

In addition to the above combination stations on the table concrete supplied by Civil Research, twelve elevation monitoring stations were installed on the sole plates adjacent to the main bearing locations by construction forces. Elevation changes measured on the sole plate stations (Table VI) showed identical trends to the changes measured on the combination stations located on the support table surface (Figure 2). These findings indicate that the turbine table concrete and the sole plate act as a single unit when considering vertical differential movements. The maximum downward deflection at full load measured on Unit 6 turbine table/2/ was 0.066 cm (0.026 inches) while Units 5 and 7 displayed much larger deflection of 0.255 cm (0.100 inches)/3,4/, and 0.228 cm (0.090 inches) respectively. Unit 8, with a deflection of 0.210 cm (0.083 inch) behaved similar to Units 5 and 7.

The static operating profile, measured at the sole plate stations, is presented in Table VI and is shown graphically in Figure 7. A rapid change in the profile is noted between the generator and the LP portion of the unit. (The reading on Station B3 is questionable and should be checked some time in the future.)

Figure 2 illustrates the measured profile change of each side of the turbine table after machine support adjustments and run-up. This data is included in Table I. The illustrated profile change is the cumulative effect of Stadelman spring support adjustments (with removal of vertical stops) and vacuum forces applied during vacuum tests. Changes in column elevations could also be contributing to the profile change. Changes from the 850 MW dynamic operating profile relative to the reference profile are the influence of vacuum, temperature increase and rotational effects of the unit operating at 850 MW conditions.

## TURBINE SUPPORT COLUMNS

Support column elevation changes from 850 MW conditions relative to the static operating elevations is presented in Table II and shown in Figure 3. The general trend shows very little elevation change with some slight upward movement noted in the middle of the unit to a maximum of 0.063 cm (0.025 inch). Increases in elevation of column stations noted on these units were believed to have been caused by thermal expansion of the concrete columns located over the condenser pit. This mechanism requires review as elevation increases were noted only on one side of Units 7 and 8.

## DIFFERENTIAL HORIZONTAL MOVEMENTS

Static operating and dynamic operating alignment are summarized in Table III. The amount of horizontal deflection was minimal with a maximum movement of 0.061 inches measured. North side measurements indicated movement to the north relative to the reference stations at the ends of the turbine table. South side measurements indicated movement to the south relative to the reference stations at the ends of the turbine table. These measurements may indicate some minute growth of the turbine table concrete due to increase in temperature at 850 MW load.

## EXTENSOMETER - STADELMAN SPRING SUPPORT GAP STATIONS

Datum extensometer readings were taken across the spring support spans on January 10, 1984. A second set, the static operating measurements, after spring adjustments were taken on January 20, 1987. The dynamic operating measurements at 850 MW were taken on May 25, 1987. The data is listed in Table IV and is shown graphically in Figure 4. The reference to static operating profile is a measure of the changes occurring due to spring adjustments during vacuum tests. The dynamic operating profile illustrates the change due to operation of the unit at 850 MW relative to the static operating measurements. The dynamic operating profile shows some slight increase in gap space at the extreme west end of the unit (generator end). All other gap stations show a decrease in span with a maximum reduction of 0.174 cm (0.069 inch) occurring near the centre of the unit. At the HP end of the unit, almost no gap change was detected. The changes in gap distance at the spring supports match quite closely the table elevation changes noted earlier (see Figure 5). These trends are very similar to the findings of the work carried out on Units 5 and 7 /3,4/. Rotational effects and temperature change account for the changes shown in the dynamic operating conditions.

## PLUMB LINE MEASUREMENTS

The four plumb lines, located on the columns at the extreme corners of the turbine support table, measure the movement of the machine support table in two horizontal directions with respect to the base of the pier columns. Readings taken under dynamic operating conditions are included in Table V. The movements observed at the plumb lines were very small. A graphical presentation (Figure 6) indicates slight horizontal movement of the east end of the table towards the south, combined with a slight westward movement at west end of the table. Normally the plumb lines show a slight inward movement

of the table corners, consistent with the downward bowing of the table centre. Inexplicably, the Unit 8 readings do not match this pattern.

## SUMMARY

From the static operating profile to the 850 MW dynamic profile, a maximum downward deflection of 0.210 cm was measured in the centre of the turbine table relative to the datum station at one end of the unit. Construction installed sole plate stations indicate similar turbine table deflection trends.

The maximum deflection of 0.210 cm measured on the dynamic profile was similar to the 0.255 cm measured on Unit 5 and 0.228 cm on Unit 7, but is several times larger than the Unit 6 maximum deflection of 0.066 cm at 850 MW conditions/2/.

Turbine support columns showed generally no elevation change with a slight increase in elevation noted in columns located over the condenser pit. A maximum of 0.063 cm change was measured.

Horizontal deflection stations show minute movement towards the outside edge of the turbine table, possibly due to thermal expansion of the turbine table concrete because of increased temperatures at 850 MW conditions.

Spring support gap measurements show decreases in gap distance in the middle of the unit at 850 MW conditions relative to the static operating condition. The ends of the unit show no change or a minimal increase at 850 MW. These changes are similar to those measured at the turbine table stations.

Plumb line station measurements at 850 MW operating conditions show a slight southward movement of the turbine table as well as a slight movement toward the west.

This report has presented the final set of measurements on the Bruce NGS 'B' turbine tables, concluding the construction through commissioning monitoring program.

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REFERENCES


1. A.G. Morton. "Instrumentation Report - Bruce GS 'B' Turbo-Generators 5 to 8 - Stability Instrumentation Program". Research Division Report No 84-153-K. July 11, 1984.

2. A.G. Morton. "Bruce NGS 'B' Unit 6 - Turbo-Generator Stability Instrumentation Program". Research Division Report No 85-74-K. March 25, 1985.

3. A.G. Morton. "Bruce NGS 'B' Unit 5 - Turbo-Generator Stability Instrumentation Program". Research Division Report No 85-197-K, October 10, 1985.

4. A.G. Morton. "Bruce NGS 'B' Unit 7 - Turbo-Generator Stability Instrumentation Program". Research Division Report No 88-60-K

TABLE I

Bruce NGS 'B' Unit No 8
Turbine Table Elevation Changes 639 Elevation

| Turbine Table Station No | Datum Profile Jan 10/84 (cm) | Static Operating Profile Jan 20/87 (cm) | Dynamic Operating Profile May 26/87 (cm) | Change Jan 10/84 - Jan 20/87 (cm) | Change Jan 20/87 - May 26/87 (cm) |
|---|---|---|---|---|---|
| 13 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0.055 | -0.081 | -0.204 | -0.136 | -0.123 |
| 15 | 0.185 | 0.076 | -0.134 | -0.109 | -0.210 |
| 16 | -0.343 | -0.526 | -0.693 | -0.183 | -0.167 |
| 17 | -0.423 | -0.518 | -0.675 | -0.095 | -0.157 |
| 18 | 0.326 | 0.332 | 0.375 | +0.006 | +0.043 |
| 19 | 0.031 | 0.023 | 0.033 | -0.008 | +0.010 |
| 20 | -0.051 | -0.198 | -0.293 | -0.147 | -0.095 |
| 21 | -0.086 | -0.229 | -0.390 | -0.143 | -0.161 |
| 22 | 0.664 | 0.478 | 0.294 | -0.186 | -0.184 |
| 23 | 0.574 | 0.450 | 0.353 | -0.124 | 0.097 |
| 24 | 1.352 | 1.275 | 1.307 | -0.077 | +0.032 |

TABLE II

Bruce NGS 'B' Unit No 8
Support Column Elevation Changes 591 Elevation

| Station No | Static Operating Profile Jan 21/87 (cm) | Dynamic Operating Profile May 26/87 (cm) | Change (cm) |
|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 |
| 2 | 1.032 | 1.034 | +0.002 |
| 3 | 0.279 | 0.798 | +0.019 |
| 4 | 0.391 | 0.412 | +0.021 |
| 5 | 0.603 | 0.666 | +0.063 |
| 6 | 0.720 | 0.855 NOT LEVEL | - |
| 7 | OBSTRUCTION | 0.446 | - |
| 8 | 0.302 | 0.289 | -0.013 |
| 9 | 0.364 | 0.348 | -0.016 |
| 10 | 0.811 | 0.847 | +0.036 |
| 11 | 0.018 | 0.046 | +0.028 |
| 12 | 0.205 | 0.195 | -0.010 |

TABLE III

Bruce NGS 'B' Unit No 8
Differential Horizontal Movements 639 Level

| Station No | Static Operating Profile Jan 21/87 (inches) | Dynamic Operating Profile May 25/87 (inches) | Change (inches) |
|---|---|---|---|
| 13 | Instrument Station | Instrument Station | - |
| 14 | 3.092 | 3.082 | -0.010 |
| 15 | 3.069 | 3.075 | +0.006 |
| 16 | 3.131 | 3.146 | +0.015 |
| 17 | 3.263 | 3.316 | +0.053 |
| 18 | 3.250 | | |
| | Check Station | Check Station | - |
| 19 | Check Station 3.310 | Readings Obstructed due to heat waves | |
| 20 | 3.145 | 3.109 | -0.036 |
| 21 | 3.551 | 3.490 | -0.061 |
| 22 | 3.228 | 3.198 | -0.030 |
| 23 | 3.250 | 3.237 | -0.013 |
| 24 | Instrument Station | Instrument Station | |

NOTE: Future readings higher than Datum will indicate a reading station shift to the north.

TABLE IV

Bruce NGS 'B' Unit No 8
Spring Support Gap Measurements

| Station No | Reference Profile Jan 10/84 (cm) | Static Operating Profile Jan 20/87 (cm) | Dynamic Operating Profile May 25/87 (cm) | Change Jan 10/84 - Jan 20/87 (cm) | Change Jan 20/87 - May 25/87 (cm) |
|---|---|---|---|---|---|
| G-1 | 60.887 | 60.805 | 60.834 | -0.082 | +0.029 |
| G-2 | 60.907 | 60.812 | 60.725 | -0.095 | -0.087 |
| G-3 | 60.907 | 60.813 | 60.680 | -0.094 | -0.133 |
| G-4 | 60.905 | 60.813 | 60.706 | -0.092 | -0.107 |
| G-5 | 60.907 | 60.821 | 60.800 | -0.086 | -0.021 |
| G-6 | 71.311 | 71.273 | 71.353 | -0.038 | +0.080 |
| G-7 | 71.313 | 71.272 | 71.355 | -0.041 | +0.083 |
| G-8 | 60.915 | 60.862 | 60.804 | -0.053 | -0.058 |
| G-9 | 60.866 | 60.778 | 60.673 | -0.088 | -0.105 |
| G-10 | 60.898 | 60.796 | 60.678 | -0.102 | -0.118 |
| G-11 | 60.912 | 60.819 | 60.645 | -0.093 | -0.174 |
| G-12 | 60.913 | 60.848 | 60.872 | -0.065 | +0.024 |

TABLE V

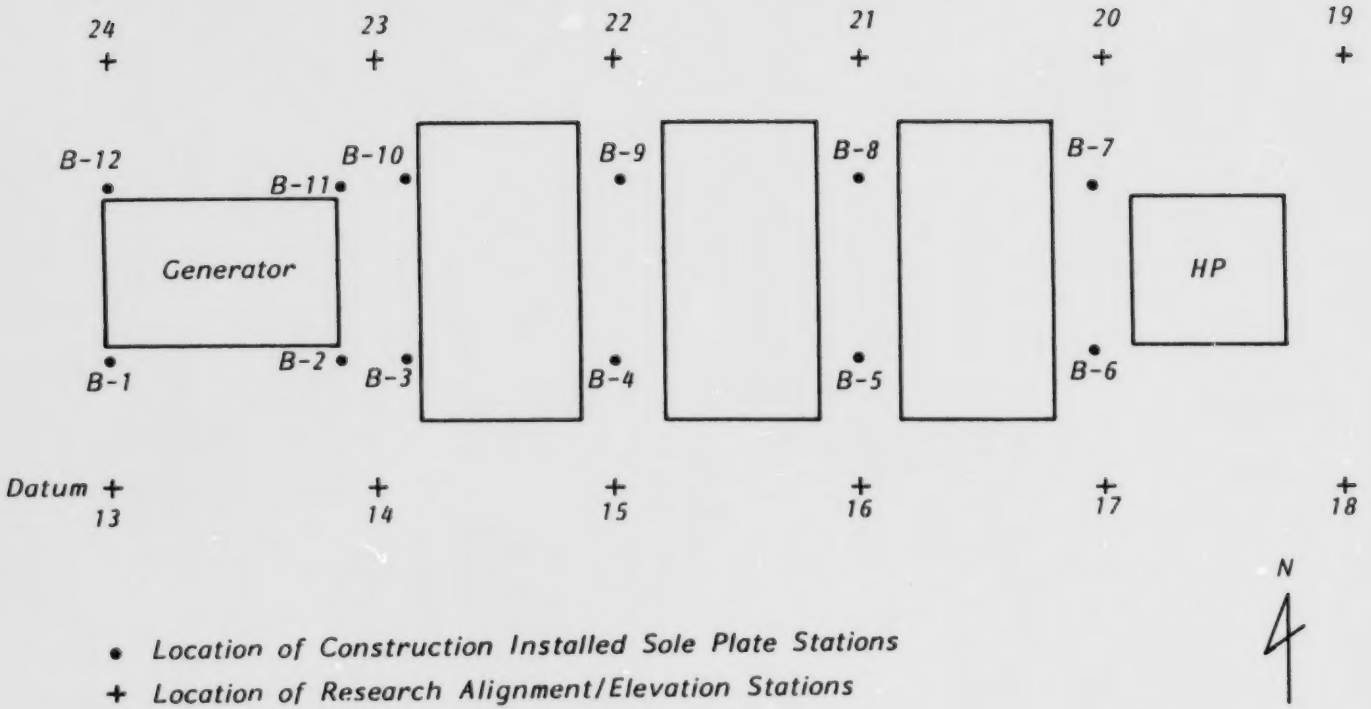
Bruce NGS 'B' Unit 8
Plumb Line Measurements

| Measuring Station No | Average Reading (North) Jan 21/87 | May 25/87 | Change (mm) | Average Reading (South) Jan 21/87 | May 25/87 | Change (mm) |
|---|---|---|---|---|---|---|
| PL1 | 12.91 | 14.05 | -1.14 | 13.30 | 11.68 | 1.62 |
| PL2 | 12.12 | 14.17 | -2.05 | 13.69 | 11.49 | 2.20 |
| PL3 | 9.89 | 10.19 | -0.30 | 16.26 | 15.21 | 1.05 |
| PL4 | 13.30 | 13.37 | -0.07 | 12.48 | 12.48 | 0.0 |
| | (East) | | | (West) | | |
| PL1 | 11.22 | 15.49 | 4.27 | 14.69 | 10.42 | 4.27 |
| PL2 | 11.86 | 11.76 | 0.10 | 14.10 | 14.10 | 0.0 |
| PL3 | 9.93 | 9.71 | 0.22 | 15.76 | 16.04 | -0.28 |
| PL4 | 11.97 | 15.64 | -3.67 | 13.79 | 10.12 | 3.67 |

TABLE V

Bruce NGS 'B' Unit No 8
Sole Plate - Static Operating Profile - Jan 21/87

| Sole Plate Station No | Static Operating Profile Jan 21/87 (cm) | Dynamic Operating Profile May 21/87 (cm) | Change (cm) |
|---|---|---|---|
| B-1 | 0.361 | 0.320 | -0.041 |
| B-2 | 0.226 | 0.117 | 0.109 |
| B-3 | 0.036 | 0.079 | -0.043 |
| B-4 | 0.175 | -0.028 | -0.203 |
| B-5 | 0.154 | -0.013 | -0.167 |
| B-6 | 0.205 | 0.069 | -0.136 |
| B-7 | 0.183 | 0.119 | -0.064 |
| B-8 | 0.104 | - | - |
| B-9 | 0.124 | -0.066 | -0.190 |
| B-10 | 0.180 | 0.061 | 0.119 |
| B-11 | 0.067 | 0.099 | +0.032 |
| B-12 | 0.123 | 0.335 | 0.212 |




• *Location of Construction Installed Sole Plate Stations*

\+ *Location of Research Alignment/Elevation Stations*

*Note: Sta 13 is the Datum or Reference Station*

*All Differentials Shown Are Relative to Sta 13*

FIGURE 1

BRUCE NGS 'B' UNIT NO 8
SURVEY PIN LOCATIONS/SOLE PLATE STATIONS



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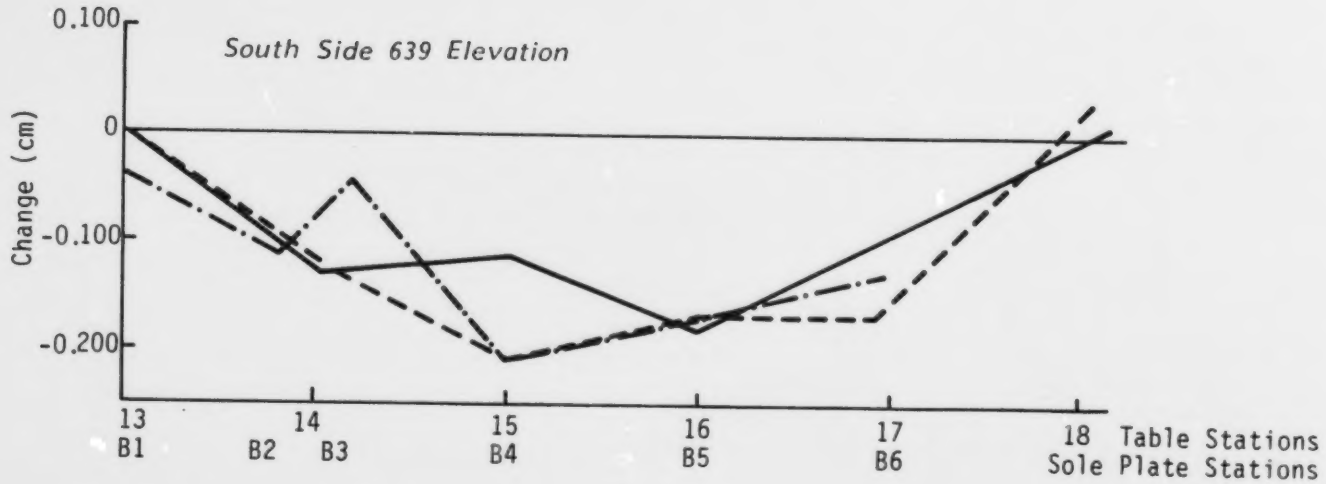
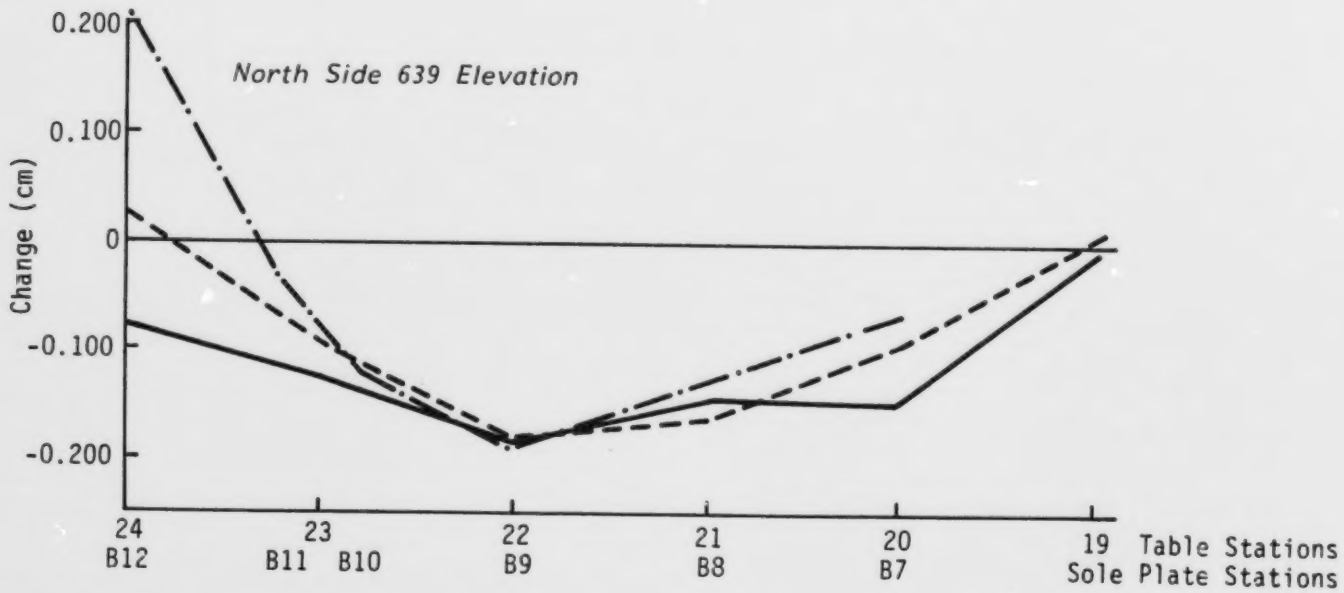



*Profile Change*

- *Reference to Static Operating Profile*
- *Static Operating to Dynamic Operating*
- *(Sole Plates) Static Operating to Dynamic Operating*

FIGURE 2

BRUCE NGS 'B' UNIT NO 8
TURBINE TABLE PROFILE CHANGES

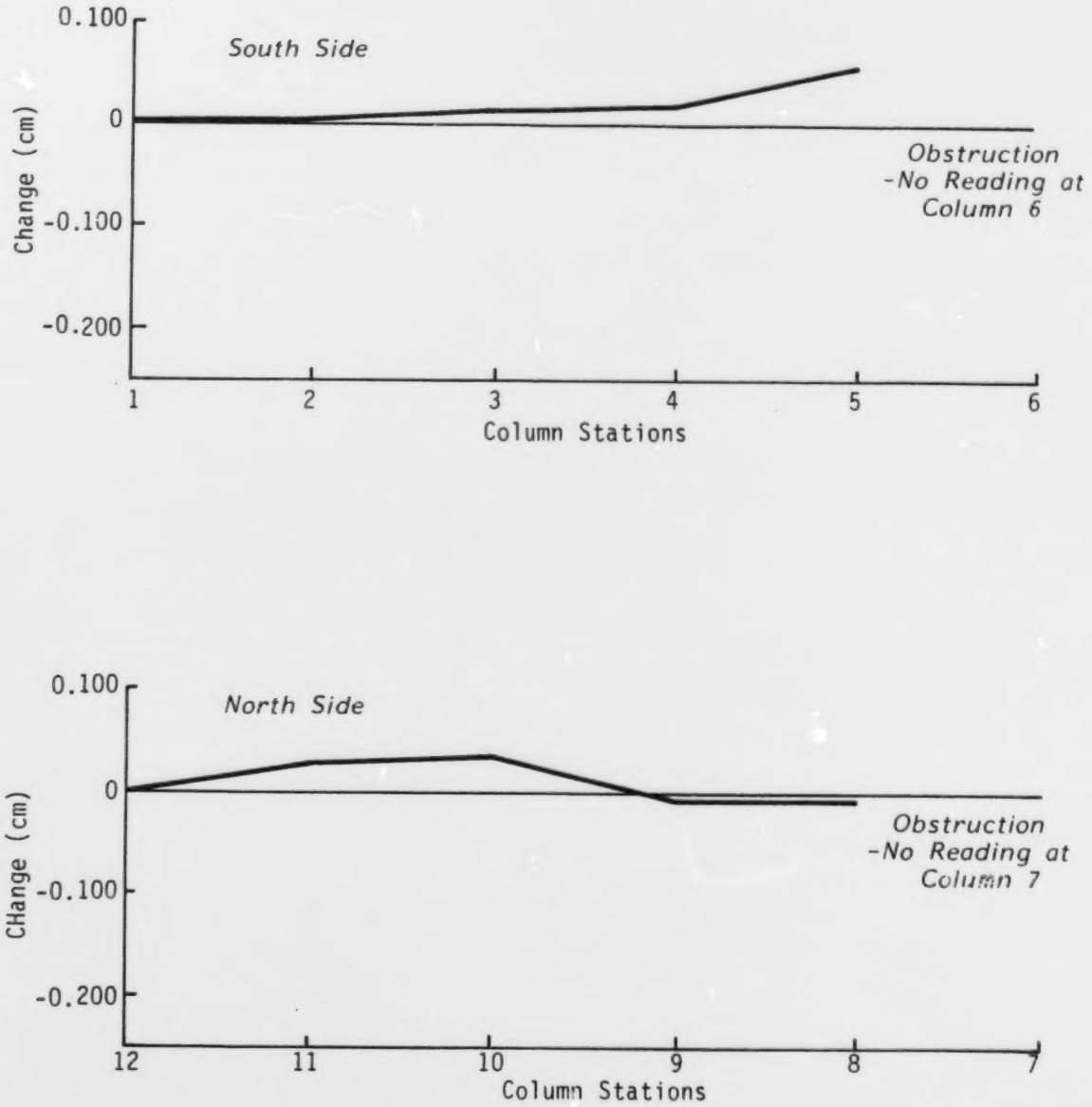



FIGURE 3

BRUCE NGS 'B' UNIT NO 8
TURBINE SUPPORT COLUMN PROFILE CHANGES
593'6 ELEV

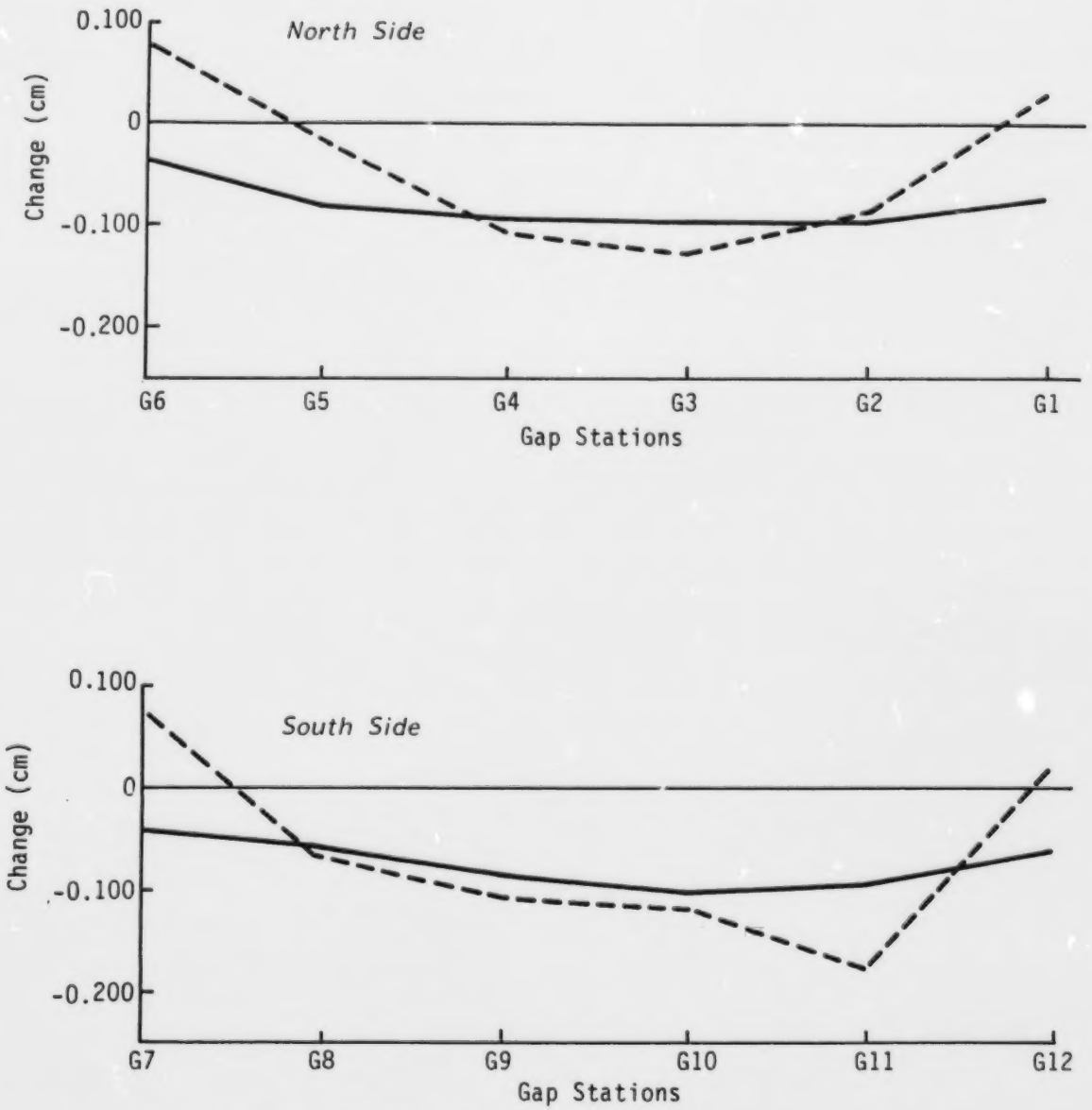



FIGURE 4

BRUCE NGS 'B' UNIT NO 8
SPRING SUPPORT GAP MEASUREMENTS

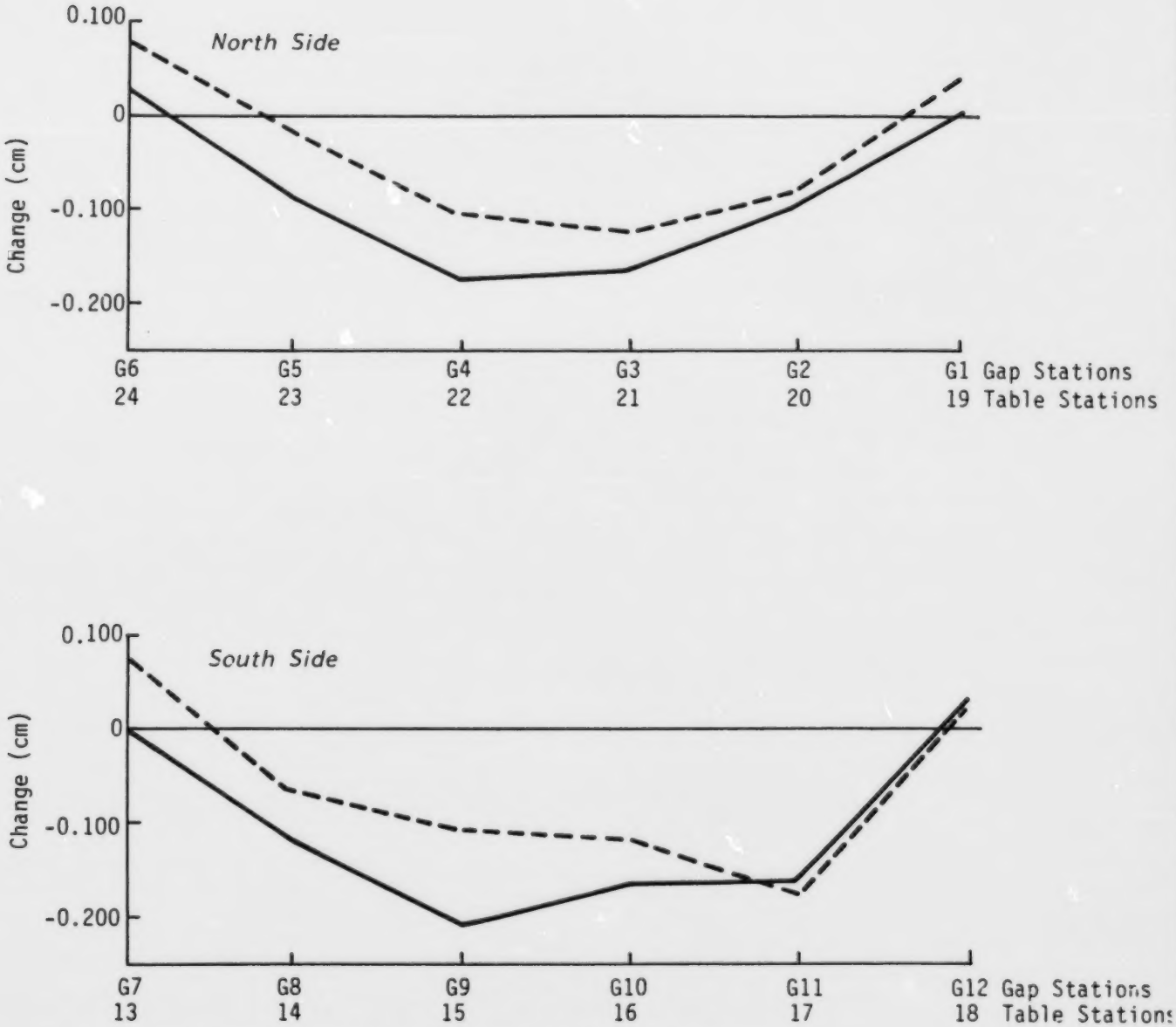



FIGURE 5

BRUCE NGS 'B' UNIT NO 8
SPRING SUPPORT GAP CHANGES VS
TURBINE TABLE PROFILE CHANGES

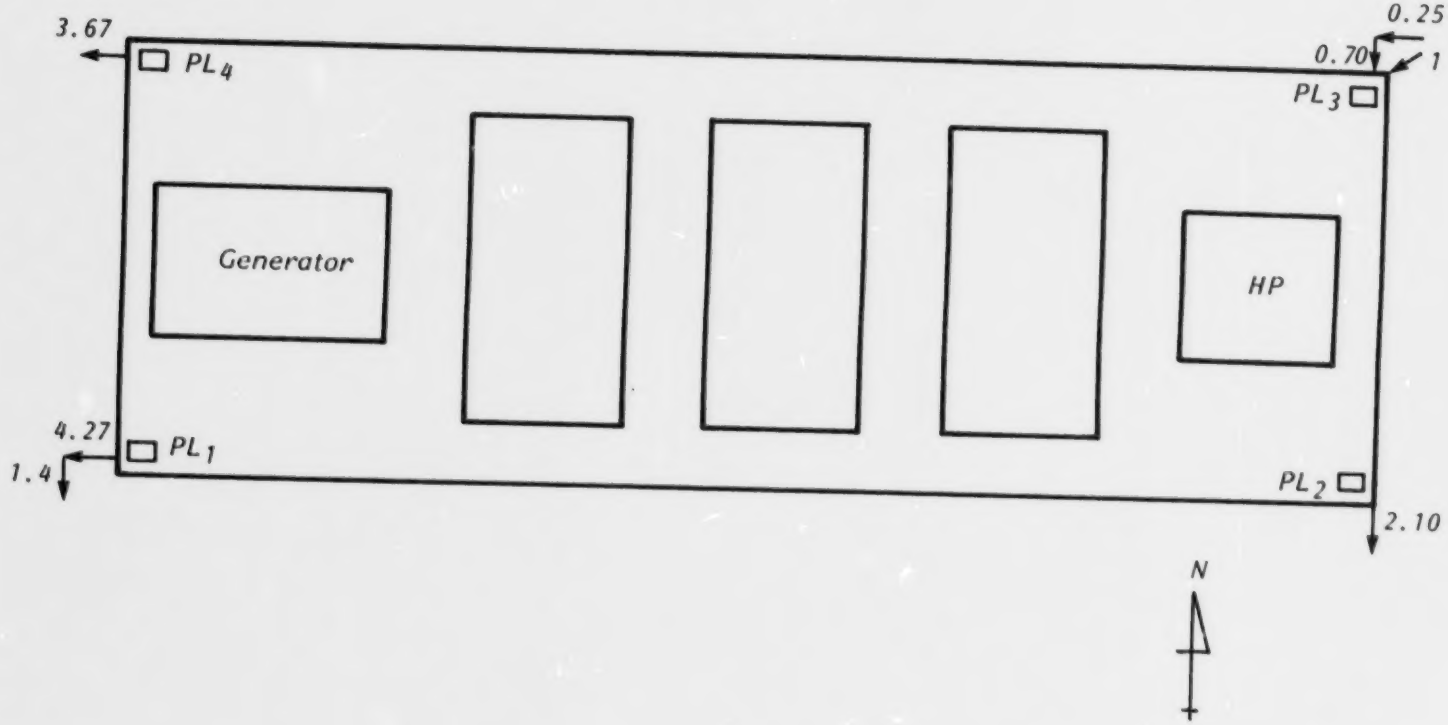
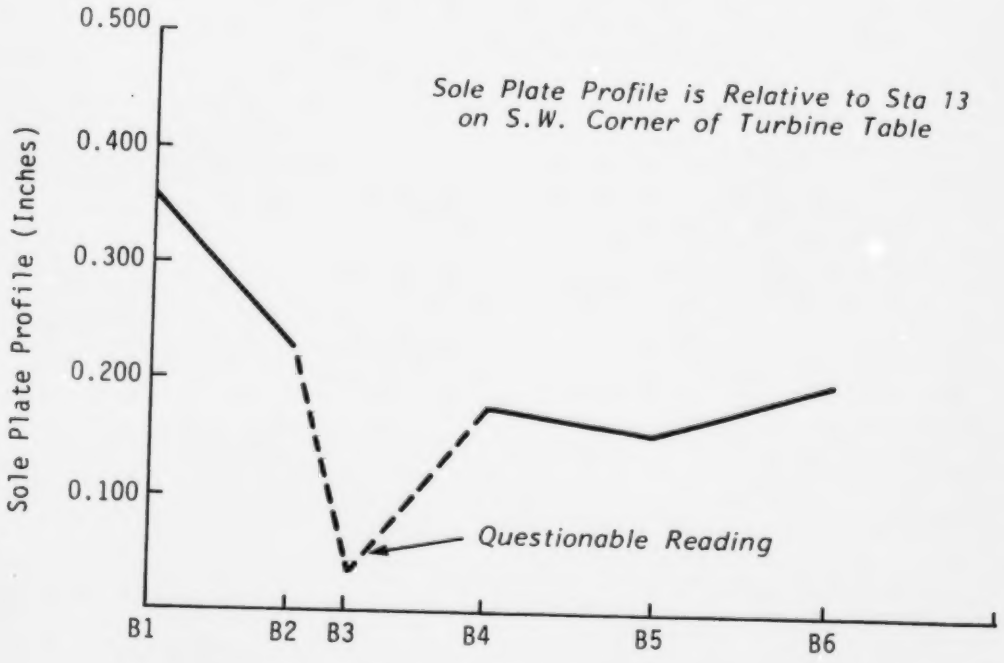



FIGURE 6

BRUCE NGS 'B' UNIT 8
PLUMB LINE INDICATIONS




BRUCE NGS 'B' UNIT NO 8
SOLE PLATE PROFILE - SOUTH SIDE

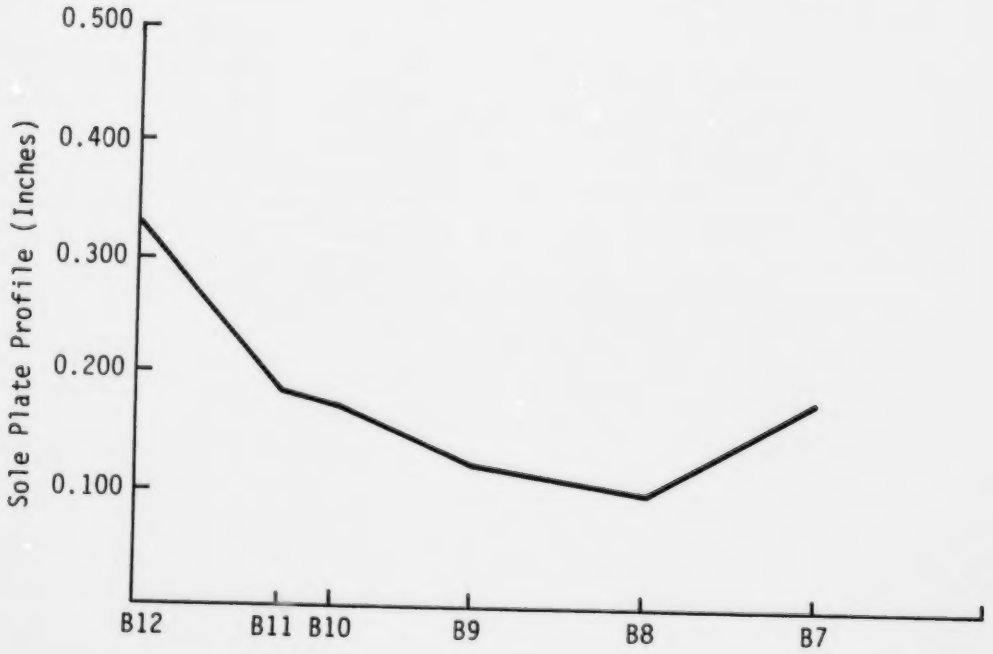



FIGURE 7
BRUCE NGS 'B' UNIT NO 8
SOLE PLATE PROFILE - NORTH SIDE